Enclosure 1
(Application No. 10/754,800; Office Action 2, mailed 12/23/2005)

~~Method of Defense-in-Depth Ultrasound Intrusion Detection~~
METHOD OF DEFENSE-IN-DEPTH ULTRASOUND INTRUSION DETECTION

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U.S. Cl. .... **367/93**; 367/99; 73/628; ~~340/554~~.

Field of Search .... **73**/570, 584, 592, 625-628; **109**/38, 40; **340**/425,426, 431, 505, 522, 539, 540, 541, 545.3, 552, 554, 568, 573, 683, 825.3, 988; **342**/28; **348**/163; **367**/1, 5, 13, 87, 88, 93, 99.

~~References Cited~~
RELATED REFERENCES CITED

U.S. PATENT DOCUMENTS

4,582,065	4/1986	Adams	73/626
4,644,509	2/1987	Kiewit, et al.	367/87
4,677,852	7/1987	Pinyan	73/628
4,733,562	3/1988	Saugeon	73/626
4,949,074	8/1990	D'Ambrosia, et al.	340/552
5,231,608	7/1993	Matsui	367/93
5,483,224	1/1996	Rankin, et al.	340/539
5,761,155	6/1998	Eccardt, et al.	367/99
5,872,516	2/1999	Bonge	340/573
5,912,620	6/1999	Lin	340/554
5,920,521	7/1999	Kromer, et al.	367/93
5,930,199	7/1999	Wilk	367/88
6,256,263 B1	7/2001	Stevens	367/1
6,304,179 B1	10/2001	Lotito, et al.	340/545.3
6,411,202 B1	6/2002	Gal, et al.	340/425.5
6,430,988	8/2002	Watanabe	73/592
2004/0140886 A1	7/2004	Cleveland	340/431

CROSS-REFERENCE TO RELATED APPLICATIONS

2004/0140886 A1 7/2004; Inventors: Ronald Cleveland and Steve Wendler; U.S. Class:340/431.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable.

THE NAMES OF THE PARTIES TO A JOINT RESEARCH AGREEMENT

Not Applicable.

INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

Not Applicable.

REFERENCE TO A "MICROFICHE APPENDIX"

Not Applicable.

~~FIELD OF THE INVENTION~~

~~The invention relates to the acoustic wave methods and systems for presence or movement detection and for distance or direction finding in the case of having a plurality of ultrasound type transmitter and receiver transducers. In particular this invention refers to condition responsive early indicating systems that exploit the registration of an occasional disturbance of ultrasonic wave beams in the manner of their reflection, refraction by edge diffraction and interference by shadowing, which disturbance has been made created by either an intruding subject or a trespasser.~~

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to the acoustic wave methods and systems for presence or movement detection and for distance or direction finding in the case of having a plurality of ultrasound type transmitter and receiver transducers. In particular this invention refers to condition responsive early indicating systems that exploit the registration of an occasional disturbance of ultrasonic wave beams in the manner of their reflection, refraction by edge diffraction and interference by shadowing, which disturbance has been made ~~created~~ by either an intruding subject or a trespasser.

Description of Related Art

At ~~the~~ present there exist methods and systems of ultrasound intrusion detection in an entire volumetric surveillance areas, in which areas there are being used different arrangements of transmitting and receiving transducers, at least namely:

- fan-shaped or matrix arrangements of transmitter and receiver transducers for stationary vector directing surveillance, e.g. U.S. Patents #5,920,521 and #4,582,065 respectively;
- solitary arrangement of ~~transmitter-receiver~~ transmitter and receiver couples for scanning all over the surveyed area with narrow clusters of ultrasound beams, e.g. US 2004/0140886 A1; U.S. Patents #4,644,509; #5,309,144;
- multi-seat arrangement of receivers along the perimeter of protected area for detecting an occurrence of ingress or ~~aggress~~ egress intrusion thru the vicinity of protected area perimeter, e.g. U.S. ~~Patent~~ Patents #5,483,224 and #5,872,516;
- single-row or multi-row arrangement of transmitting and receiving transducers for realizing various processing operations with the help of reflected ultrasound beams, in particular:
  - - detection any strange subject inside the surveyed area, e.g. U.S. Patents #5,761,155, #6,411,202 B1 and #6,518,915B2;
  - - measurement of distance to intruded subjects or to the level of interface of liquid and granular materials, e.g. U.S. Patents #4,949,074, #5,231,608 and #5,131,271, #6,323,441B1 respectively;
- isolated arrangement of transmitter inside an enclosed area and positioning the receiver outside this enclosed area with the aim of detecting an occurrence of destroying the isolation of said protected area by an intruder, e.g. U.S. Patents #4,807,255, #5,638,048, #6,430,988.

As is evident from the delivered above the elucidative examples, the modern methods and systems for ultrasound intrusion detection utilize preferably the phenomenon of reflection of ultrasound beams from strange subjects that ~~have~~ occurred inside a surveyed area. Meanwhile, it is the known fact that the process of emitting-reception of airborne ultrasound signals depends strongly upon air ambient conditions (temperature, moisture, atmospheric pressure, etc.) and therefore it is restricted spatially. In turn, this restriction predicts the limitations upon volumetric dimensions of surveyed area and consequently on the capability of earlier warning detection of either an intruding ~~object~~ subject or a trespasser. The alternative enhancement of the entire protected space might be realized by attaching to the ultrasound-surveyed area the proper number of adjacent areas, which areas were being surveyed with use of different physical principles of intrusion detection (infrared, microwave, light level sensing, etc.), e.g. see U.S. Patents #4,857,912 and #6,127,926. Unfortunately, such a would-be method and arrangement will lead to hardware and software complexity, low reliability and great cost of an intrusion protection system as a whole. Nevertheless, it is necessary to establish such very method of intrusion protection that features with high reliability and ~~self-security~~ self-defense, and meets the ~~proper~~ requirements to the multi-echelon arrangement of the protection systems of critical objects. Those ~~crucial~~ strong requirements are delivered at least in the following regulations for such evidently critical objects as Nuclear Power Plants:

- Defense-in-Depth in Nuclear Safety, IAEA INSAG-10, IAEA, Vienna, 1996.
- Method for Performing Diversity and Defense-in-Depth Analysis of Reactor Protection Systems. NUREG for U.S.NRC/Prepared by G.G. Preckshot-Lawrence Livermore National Laboratory/Manuscript date: December 1994.

Furthermore, it seems to be relevant to emphasize some unique features of ultrasound that make it attractive for the purpose of faultless intrusion protection of a near field zone, namely:

- ultrasound waves are being emitted in the form of narrow directional ~~beam~~ beams and consequently do not travel around corners well, so beam patterns of the said directional ~~beam~~ beams may be easily reflected ~~and/~~ or shielded by an intruded subject; or they may be refracted, i.e. diffracted by the edge of ~~an object~~ a subject having penetrated them into small part of their peripheral lobes;
- narrow ~~spatial~~ solid angle of directional reception of airborne ultrasound may be obtained with relatively small dimensions of hidden receivers;
- ultrasound is not influenced by regular "white noise" of an environment, especially by an industrial ambient, being either inside or outside.

Besides, at the present time the ultrasound processing methods and instruments are being well practiced in even multi-modular hierarchical imaging, detecting and measuring systems that contain the similar ultrasonic instrumentation and hence are reliable, convenient and low-cost. This real ~~processing advancement~~ advancement of the processing architecture is the actual prerequisite for improving ~~an intrusion protection with use of~~ ultrasound intrusion protection technology, which the present invention is devoted to.

BRIEF SUMMARY OF THE INVENTION

With the aim of ~~proper introducing~~ introduction into the sense and art ~~the mentioned above relevant specifity~~ of the novel ultrasound intrusion detection technology provided by the present invention, it is necessary to identify the new basic objects of concern, as it is set forth below.

The principle object of the present invention is to establish a method of anticipatory ultrasound intrusion detection that enables the purposeful application of all the advantageous features of ultrasound technology for ~~arranging the reliable early and~~ sufficient enhancement of remote ability of preventive defense-in-depth ingress or ~~aggress~~ egress intrusion detection ~~process in the limits of~~ throughout the ~~multi-echelon dome-type volumetric~~ ~~space~~ near field zone and circumjacent vicinity around a surveyed critical ~~installation~~ object.

Other object of the invention is to arrange the whole protected dome-type volumetric room around a critical ~~installation~~ object in several juxtaposed areas, ~~which areas represent various echelons of the entire defense-in-depth intrusion detection volumetric space~~ hence to create the multi-echelon structure in the form of multi-level solid openwork frame, outlined over the near field zone and circumjacent vicinity of a protected object regarding the remote ability of propagation of airborne ultrasound waves along their incidence and reflection trip at the forecasted atmospheric conditions of the air ambient.

Further object of the invention is to determine ~~choose~~ ~~properly~~ the geometrical shapes and dimensions of ~~these~~ 2-D polygonal or curvilinear areas, or 3-D curved ~~surface~~ surfaces ~~areas~~ of those echelons in correspondence with the spatio-temporal parameters of air-borne ultrasound propagation and the available capabilities of selected ultrasound beam patterns to cover all the said 2-D ~~curvilinear~~ areas or 3-D ~~curved~~ surfaces with stationary or scanning said ultrasound beam patterns ~~the relevant~~. In turn, the selection of suitable beam patterns' characteristics (i.e. frequency range of a chosen transducer, effective transmitting-receiving distance of signals, solid angle of ultrasound beam pattern, rate of ultrasound attenuation, etc.) should be done with respect to the statistically forecasted conditions of ultrasound beam patterns' propagation in the air ambient around a protected object, e.g.

the annual average of temperature, humidity, atmospheric pressure, ~~deflecting~~ cross wind flows, etc.[[).]]

Another object of the invention is to compose a graphic-analytical model of intrusion vulnerability for each individual echelon, taking to consideration the real layout of protected object and the ~~options~~ optional models of spatio-temporal ~~purposeful~~ behavior of intruder or trespasser on their assumed routings, and the chosen mode of response of the emitted ultrasound signals (i.e. reflection, refraction by edge diffraction and interference by shadowing).

The other object of the invention is to choose and assign for each echelon the ~~appropriate~~ pertain method of ultrasound intrusion detection regarding the ~~type~~ said mode of ultrasonic beam ~~responding~~ response, ~~i.e. reflection, refraction and interference~~ which should match the ~~created by~~ predetermined behavior of ~~either~~ an intruding subject or a trespasser on their presumptive routings.

The further object of the invention is to compose the generalized graphic-analytical model of intrusion vulnerability for the entire protected dome-type volumetric multi-echelon structure that is being outlined in the form of multi-level solid openwork frame over the near field zone and circumjacent vicinity ~~space~~ around a critical ~~installation~~ object. This generalized model must ~~properly~~ establish ~~an operatively reliable and functionally~~ the logically correct interrelation amongst ~~different adjacent~~ juxtaposed and even non-adjacent echelons that is destined to intrusion justification, ~~issuing~~ presentation of alarm signals, and ~~activating~~ actuation the protective and defensive measures. This interrelation is based on the principle of early and preventive ultrasound detection of ingress or ~~aggress~~ egress intrusion, where the said principle consists in gradual generating of caution, self-checking, intrusion vindication, and alarm and security activating signals in the result of ~~logic~~ logical processing of ultrasound signals acquired during continuous status scan of detectors in all the echelons.

Still further object of the invention is to minimize the diversity of hardware and software that should be utilized for ~~of~~ all different ultrasound beams' response modes ~~techniques of ultrasound intrusion detection~~ involved, and to compose finally the mutual set of instruments and ~~logic~~ control software algorithm for the entire defense-in-depth ultrasound intrusion detection and justification procedure. It is evident that minimized architecture of hardware should be based on the conjugation of specification figures of various ultrasound instruments, at least operating frequency and bandwidth of ultrasound emission, S/N ratio, type of signal processing domain, that are destined for practicing different beam pattern's response modes, i.e. reflection, refraction by edge diffraction, and interference by shadowing the emitted beam pattern with a target. The software apparently should represent an algorithm ~~in the form of information and processing logic matrix~~, which is being compiled on the basis

of ~~the Event Tree of~~ ~~intrusion~~ modeling of the intrusion event tree. This software algorithm should ~~interpret mathematically the Goal Function of~~ accomplish logical operations for ~~issuing~~ presentation of the signals of intrusion detection, justification and prevention in the result of logical processing of caution and self-checking signals, acquired during continuous status scan of ultrasound detectors (i.e. receivers and transceivers) in all the echelons of the intrusion protection dome-type volumetric room.

The specific content of the invention, as well as other objects and advantages thereof, will clearly appear from the following description and accompanying figures.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS ~~FIGURES~~

Preferred embodiments of the present invention will now be described with reference to the figures by way of illustration, in which the fundamentals of the suggested novel method of ultrasound multi-echelon intrusion detection are represented, in which like reference characters indicate like elements of method's arrangement, in which explanations of said arrangement are given, and in which:

FIG.1 shows schematically an alternative embodiment of a defense-in-depth ultrasound multi-echelon intrusion detection ~~space~~ spatial structure ~~that, accordingly~~ in the form of multi-level solid openwork frame, outlined over the near field zone and circumjacent vicinity of a protected object, which structure provides for the enhanced remote ability of propagation of the airborne ultrasound waves. Accordingly to the present invention, this structure has been arranged in possession of juxtaposed ~~the in-built~~ the central (C), short-range (S) and long-range (L) areas. These areas ~~principally~~ represent the corresponding echelons of said ingress or ~~aggress~~ egress ultrasound intrusion detection volumetric room ~~with various~~ ~~types~~ ~~modes of ultrasound~~ ~~beam~~ beams[[']] ~~response~~ ~~involved~~. As shown at **FIG.1**, the ~~in-built~~ central echelon **C** is being arranged inside the premises of the enclosed housing of a protected critical ~~installation~~ object **1**. In this ~~in-built~~ closed echelon there is being used the ultrasound intrusion detection by the stationary vector directing or space scanning ~~scan conversion~~ techniques with ~~reflecting~~ reflection and ~~refracting~~ refraction by edge diffraction response of ultrasound beams. The ~~transmitter-receiver~~ sets of transmitters and receivers are being mounted inside the premises of this ~~installation~~ object **1**. According to the present invention, in the alternate embodiment of the method thereof, transmitters may be mounted inside each of the premises of the ~~installation~~ object **1**, ~~but~~ while receivers correspondingly are mounted outside these premises for detecting any ~~breaking~~ breakage of their enclosures (broken walls, ~~opening~~ opened doors, windows, etc.). That case the receivers may be mounted at the peripheral outline of echelon **C**, where the adjacent echelon **S** begins.

The short-range echelon **S** is being shaped in the form of the 2-D polygonal or curvilinear areas, or 3-D curved surface ~~area~~ areas at the ~~direct~~ adjoining vicinity of external peripheral outline ~~of~~ over the buildings with said enclosed ~~housing~~ premises and over the other outdoor installations of a protected critical ~~installation~~ object~~, which~~ ~~respectively.~~ ~~Respectively~~ Evidently, the inner outline of echelon **S** is ~~either~~ the substantial ~~plane~~ planar or volumetric solid openwork frame. In the short-range echelon **S** there is being used the ultrasound intrusion detection by the stationary vector directing or space scanning technique with ~~refracting~~ refraction by edge diffraction response or with interference by shadowing response of ultrasound beams in the result of respectively ~~intersecting~~ intersection or shielding of these beams by an intruding subject or a trespasser. ~~The at~~

At least one long-range echelon **L** is being arranged outwardly and adjacently to ~~outside~~ the outer peripheral outline of the short-range echelon **S**. In the long-range echelon **L** there is being used the ultrasound intrusion detection by preferably the stationary vector directing technique with an occasional ~~reflecting~~ reflection response of ultrasound beams from the surface of an intruded subject.

FIG.2 shows the verifying logic matrix that represents the logical interrelation of ultrasound detection signals, acquired from different juxtaposed and non-adjacent echelons **C**, **S** and **L**. Since this logic of signals is being used for intrusion justification, the ~~The~~ self-checking signals are being foreseen for every echelon that enables to analyze ~~the spatio-temporal behavior of intruder and~~ the current ~~operational state~~ operating status of each ~~surveying~~ echelon. The simultaneous appearance of caution and positive self-checking signals should vindicate that an intrusion has occurred in the checked echelon.

DETAILED DESCRIPTION OF THE ~~PREFFERED EMBODIMENTS~~ INVENTION

The preferable embodiments of the present invention are being unveiled by the description of the ~~logical interrelation~~ innovative approach to the use of various ultrasound detection techniques and their ~~logic~~ logical interrelation that ~~have been purposefully involved into~~ constitute the basic content of the novel Method of Defense-in-Depth Ultrasound Intrusion Detection. The following detailed description is expected to deliver the appropriate explanation to advantages of these techniques and their beneficial interaction in ultrasound early and anticipatory intrusion detection procedure.

~~Let it be assumed that there exists~~ At least one of the vital secure needs of a critical object (e.g. Nuclear Power Plant, refinery, offshore rig, flowing plant of gas-main pipeline, moored ship, plane station, helipad, etc.) ~~installation, which needs~~ is that of the reliable and stealthy intrusion protection system, see **FIG.1**. The protection reliability is to be enabled by use of early and preventive detection

of an intruder or trespasser. The secrecy, in turn, may be realized thereto by utilizing ultrasound technology for detecting the presence or motion of ~~objects~~ subjects, because it is difficult to notice or suppress ultrasound waves in air without special detectors and suppressing generators respectively. The presence or motion of suspected ~~object~~ subject within a surveyed area should result in ~~reflecting~~ reflection[[,]]; ~~refracting~~ refraction by edge diffraction or interference by shadowing of the airborne narrowly directed ultrasound beams. Keeping in mind that ultrasound attenuates in air quickly enough, it seams ~~be~~ reasonable to arrange the whole protected room around a critical ~~installation~~ object in several juxtaposed inside and /or outside areas. These ~~which~~ areas represent ~~consequently adjacent~~ juxtaposed echelons of the entire defense-in-depth intrusion protection dome-shaped volumetric ~~multi-echelon~~ structure ~~in the form of multi-level solid openwork frame, outlined over the near field zone and circumjacent vicinity of a protected object~~ ~~space~~. The number of echelons, ~~and~~ their shape and space dimensions depend upon the real layout of a protected object, the amount of ~~whole~~ protected volumetric room, the ~~known~~ available spatial-temporal parameters of the airborne ultrasound propagation in forecasted conditions of the air ambient, and the predetermined behavior of an intruder or trespasser on their assumed routings.

The said expected behavior predestines correct ~~chose~~ selection of relevant ultrasonic detecting technique and instrumentation for each surveyed echelon. ~~Consequently,~~ In compliance with the present invention the said system of the ultrasound defense-in-depth protection of the entire surveyed room must be ~~is being~~ ~~realized with~~ ~~an appropriate~~ organized ~~informational~~ in data interaction format that includes ~~in~~ ~~logically~~ ~~exhaust~~ ~~signal~~ logical processing of acquired signals according to the fallowing signal justification ~~sequence~~ procedures:

- simultaneous location inside all the echelons with forming the ~~*warning*~~ *caution signals* in case of presence or motion of suspected ~~objects~~ subjects at least in one of the said echelons;
- keeping under surveillance the motion of suspected ~~objects~~ subjects throughout the juxtaposed and non-adjacent echelons with forming the *intrusion* ~~*vindicating*~~ *vindication signals*, if this motion is defined as an intrusion that threatens the protected critical ~~installation~~ object;
- forming *self-checking signals* for verification of an intrusion occurrence and current check of performance reliability of ultrasound detection facilities of every echelon;
- logically processing the ~~*warning*~~ *caution signals* and *intrusion* ~~*vindicating*~~ *vindication signals*, and ~~releasing~~ presentation of the *alarm signal* as well as the necessary ~~operation signals~~ *security activating signals* in accordance with the designed ~~*Goal Function*~~ goal function of the said ultrasound detection and protection technology of the present invention ~~procedure~~.

As it is shown at **FIG.1**, the whole room around a critical object is being arranged at least in three juxtaposed areas that are defined as central ~~in-built~~ ~~(C)~~ C, short-range ~~(S)~~ S and long-range ~~(L)~~ L echelons. The ~~in-built~~ central echelon **C** is being arranged inside the normally enclosed at least one premise ~~of a~~ with the protected installation of a critical object **1** that optionally is placed on a supporting base **2** acting as a passive protection structure of said object from beneath. The inside reflecting surfaces **3** are being constructed to enclose normally said protected installation of object **1**. At least one pair of transmitter **4** and receiver **5** is being mounted inside the enclosed area of echelon **C**. Over the echelon **C** there is being arranged the internal border **6** of the short-range echelon **S**. The external border **7** of echelon **S** is being made to coincide with the frontier **8** of the open to outside the echelon **L**. In dependence on the real layout of a protected object 1 and hence on the physical volumetric shapes of surveyed echelons **C**, **S**, and **L** the said borders **6** and **7**, and frontier **8** are being configured like either 2-D polygonal or curvilinear, ~~array~~ or 3-D curved spatial surfaces of a solid openwork frame, or in any combination thereof. The internal border **6** and external border **7** of the short-range echelon **S** both are being equipped with alternate pairs of the mounted opposite each other transmitters **9** and receivers **10**, so that all of the area of echelon **S** is filled in with ultrasound ~~pattern beams~~ beam patterns **11**, which ~~beams~~ beam patterns are arranged closely and directed ~~oppositely~~ opposite each other. If the dimension of echelon S in the designed prevailing direction of ultrasound location is bigger than the admitted value of the airborne ultrasound wave attenuation along its one-way emission trip from a transmitter to the opposite receiver, the said echelon should be divided into several ~~sub-levels~~ sublevels. The dimension of each of said ~~sub-levels~~ sublevel in said prevailing direction of location must provide for such admissible value of ultrasound attenuation in the forecasted conditions of the air ambient where the received signal is not less than the dead band of the ultrasonic receiver chosen for the said conditions of the air ambient. The outer surface of solid openwork frame of frontier **8** of echelon **L** is equipped ~~(preferably chequerwise)~~ with integrated transmitter-receiver transducers, i.e. transceivers **12**, disposed in the form of preferably chequerwise lattice, so that a sort of umbrella barrage of emitted upstream ultrasound is being formed by closely adjacent beam patterns **13** where some of the transceivers **12** may be directed stationary, while another are being pivoted for scanning the solid angles that overlap each other.

The principal operational character of each echelon is based upon the chosen ultrasound detecting technique, which technique features distinctive mode of emitting of ultrasound signal and registration of its occasional disturbance regarding the expected mode of ultrasonic beam's ~~responding~~ response. Since the central echelon **C** ~~is a~~ represents at least one normally enclosed premise, it is reasonable to

use therein the technique of ultrasound echolocation. The narrow ultrasound beam **14** is being emitted inward the enclosed area of echelon **C** and consequently reflected from inner surfaces **3** in the form ~~of a pattern lobe~~ of returned beam **15**, provided these beams ~~should~~ were not ~~be~~ disturbed by the presence of an intruder. Otherwise, said ~~pattern lobe of~~ returned beam **15** will be changed and receiver **5** consequently will register an intrusion. If the integrity of enclosure ~~of installation~~ of object **1** ~~was~~ were destroyed, see dashed lines at **FIG.1** (broken walls, opened doors or hatches, etc.), the emitted beam **14** or some of the reflected beams **15** ~~should~~ would go outward in the form of released beam **16** that might be registered by one of the receivers **10** of echelon **S** [[, so in]]. In the result, an ingress or ~~aggress~~ egress intrusion should be registered ~~as well~~. Thus ~~and so~~, inside echelon **C** there ~~is~~ are being realized the couple of ultrasound techniques, namely: the ultrasound echolocation inside the enclosed premises with use of reflection of ultrasound beams; and ~~detecting~~ detection of accidentally outward released the airborne ultrasound by direct receiving its beams with receivers **10**. The arrangement of the said receivers **10** is being preliminary designed so that their beam patterns could overlap the areas of openings and expected damages of the enclosure of object **1**. ~~scan mode, which techniques are being designated for the local detection of ingress or aggress intrusion.~~ So far as echelon **S** is being designed for ~~perimeter~~ protection of proximate outside area of near field zone around the ~~installation~~ object **1**, it appeared to be reasonable to use the technique of ultrasound beam interference because an expected intruder has to cross this echelon ~~in any case on~~ along his ingress or ~~aggress~~ egress motion ~~regarding the critical installation 1~~. ~~It means that~~ In this case an intruded target **17** ~~must~~ should interfere or ~~overshadow~~ shadow the ultrasound beams **11** going from transmitters **9** to receivers **10** ~~inside~~ throughout ~~the 2-D polygonal or curvilinear areas, or 3-D curved spatial surface zones of]~~ echelon **S**. Optionally, the interference of an intruded target with the surveying beam patterns of echelon **S** may lead to refraction of said beam patterns by the edge diffraction phenomenon. It means that the refracted, i.e. edge diffracted ultrasound beam pattern should register the event of penetration of an intruding ~~object~~ subject into the small part of its peripheral lobes. This small part of in-lobe penetration is less than the wavelength of airborne ultrasound emission, which is approximately of 0.3445"or 0.875 cm. ~~for airborne ultrasound~~ ~~emission~~ at frequency of ≈ 40 kHz in normal ambient air conditions. So that, this mode of beam pattern response should provide for fast and correct detection of an intruder that tries to cross the frontiers and enter inside area of echelon S. At the ~~perimeter~~ echelon **S** there may be utilized the target detection with use techniques of ~~either~~ unit stationary vector directing, stationary vector lattice arranging or unit/group vector scanning ~~scan conversion~~ ~~techniques~~ where ~~purposely~~ selected number of receivers **10** operate in the scan mode but the rest number of receivers **10** and all

the transmitters **9** operate in stationary vector directing mode. The purpose of ~~activating~~ activation of the selected group of receivers **10** for in-phase scanning is the vindication of intruder's presence inside echelon **S** and ~~defining~~ definition of vector of its motion that represents the direction and speed thereof. Since in the alternative arrangement of the present invention echelon **S** may be divided into several adjacent ~~sub-echelons~~ subechelons S_1, S_2, S_3, ... S_{n+1}, where dimensions of each echelon are limited by the distance of feasible propagation of airborne ultrasound waves in the forecasted conditions of ambient air, the remotability of ultrasound detection inside echelon **S** should be sufficiently enhanced.

The external echelon **L** is being designed for protection of ~~all the~~ circumjacent dome-type air vicinity of the layout area of the critical ~~installation~~ object **1** with the aim of early and anticipatory intrusion detection where an intruded target **18** must be found at its trajectory **19** of approaching this protected ~~installation~~ object. Since ultrasound beams **13** of echelon **L** are being emitted continuously outward the frontier **8**, and ~~therefore~~ since they may return only when ~~being~~ having been reflected from a random target in the form of reflected beams **20**, it appeared to be reasonable to apply the ~~technique of~~ ultrasound beam reflection with use of ~~either~~ stationary vector directing, stationary vector lattice arranging or unit/group vector scanning ~~scan conversion~~ techniques where the selected number of transmitter-receiver transducers **12** may operate in stationary vector directing mode and the rest number of said transducers may operate in the volumetric scan mode. The solid openwork frames of echelons **S** and **L** may be designed for 2-D polygonal or curvilinear, or 3-D curved surface array arrangement of pairs of transducers **9** and receivers **10** (echelon **S**), and of transmitter-receiver transducers **12** (echelon **L**) in dependence on the layout and enveloping space shape of the protected buildings and outdoor installation of the object **1**. The purposeful choice of one of said techniques of ultrasound emitting-receiving and said arrangement of transmitter-receiver transducers **12** are being done in dependence ~~of~~ on the preliminary assumed graphic-analytical model of intrusion vulnerability of the long-range echelon **L**. Since the behavior of target **18** inside echelon **L** is really crucial for all the consequent intrusion protection activity, there is being organized the estimation of the main parameters of said behavior. For example, ~~analyzing~~ the analysis of the changes of dimension **H** and speed of an approaching subject in time and value, see **FIG.1**, may ~~assess~~ run the assessment of the threatening approach of target **18** to ~~the installation~~ a protected object **1** or may indicate the invulnerable passing by of the said subject. Optionally, Doppler ~~detection~~ effect may be used for intrusion detection and signal processing inside area of the long-range echelon **L**.

~~This~~ The ~~logic~~ verifying logical matrix, shown at **FIG.2**, enables to ~~analyze~~ organize the systematized programmable analysis of the directional sequence of retrieved signals and to assess ~~respectively~~ direction, intensity and at ~~least~~ last the real security threat of intrusion to the ~~protected installation~~ buildings, works and installations of a protected object **1**. This ~~very~~ analysis of real security menace ~~and assessment~~ is being accomplished with respect to the preliminary composed the local echelons' graphic-analytical models of predictive vulnerability for each of the echelons and the generalized ~~the~~ graphic-analytical ~~models~~ model of the presumptive intrusion vulnerability for all the multi-echelon protective structure. ~~The~~ Each of the local echelon's graphic-analytical ~~model~~ models is being composed in accordance with the real layout of the protected echelon and ~~forecasted~~ presumptive spatio-temporal behavior of an intruder, and with the ~~utilized~~ ultrasound detecting technique ~~as it was described here before~~ of ~~emitting-responding~~ emission-response, chosen for each echelon **C**, **S** and **L** ~~[regarding the task that each of those echelons has been commissioned with]~~. If to say rather more detailed, the working-out of the graphic-analytical model of intrusion vulnerability for each echelon is being accomplished with regard to the supposed options of spatio-temporal purposeful behavior of intruder or trespasser along their possible routings inside premises of the central echelon **C**, around buildings and works of short-range echelon **S**, within reach of ultrasound location inside the space of the long-range echelon **L**. The said options of ingress or egress routings of intruder or trespasser thru every echelon are also being searched with taking to account the layout and architectural features of the available protective barriers against an intrusion, and various assumed ways of the trespassers' accessibility to the critical works and installations therein. The results of search of the said options are being used for verification of geometrical shape of every echelon by comparison of spatio-temporal parameters of intruder's or trespasser's purposeful behavior with spatio-temporal parameters of ultrasound beams' propagation and signaling response in prevailing directions of location. Then the echelons' logical equations are being set up in advance to reveal the factors of menaces inside the echelons and sublevels therein based on the said graphic-analytical models of intrusion vulnerability that consists in the failure probability of protected facilities. This vulnerability should be increased for facilities, which belong to some sublevels inside one echelon or to different echelons at the same time.

The generalized graphic-analytical model is being compiled with taking to consideration the ~~specifity~~ specificity of each local echelon's model and the ~~appropriate~~ software-programmable inter-echelon informational and processing ~~logic]~~ logical interaction among sublevels of each echelon and among ~~adjacent~~ juxtaposed and non-adjacent echelons[[,]]. See ~~see~~ **FIG.2**[[,]] that illustrates the inter-

echelon tracing of an intruding subject or a trespasser. The said generalized graphic-analytical model is being prepared, including the steps of:

- designation of available physical barriers for having used them as hindrances to access the critical installations and as entrapments along the presumed routings of an intruding subject or a trespasser where this designation is being fulfilled regarding the previously simulated model of the presumptive spatio-temporal behavior of an intruding subject or a trespasser; and
- definition of the territorial contours and limits of operating time, violation of which with the non-authorized presence or movement of an intruded subject or a trespasser should be considered as the actual hazardous intrusion; and
- plotting the intrusion event tree in the form of graphic representation or table matrices which identify the interrelations of sublevels inside any echelon, and among juxtaposed or non-adjacent echelons that are based on the sequence of the cause-effect events of registration of an intrusion occurrence and definition of the vulnerability and menaces due to the presence and motion of an intruded subject or trespasser; and
- accomplishment of the graphic presentation of intrusion event tree on the floor plans of enclosed premises of echelon **C** and on the lay-out of the near field zone of echelon **S** for detection of intrusion cause-effect cross-linkages and respective facts of intrusion menaces among sublevels inside echelons, and among juxtaposed and non-adjacent echelons **C**, **S** and **L**; and further
- setting up the generalized graphic-analytical model itself in the form of graphic-analytical representation of inter-echelon dependable vulnerability at occurrence of one or a few intrusions in one of the echelons, or in some of them simultaneously.

So that, the generalized graphic-analytical model and verifying logical matrix, see **FIG.2**, are ~~is~~ being ~~built on the basis of~~ used for prediction of the variable vector of the assumed intruder's threatening motion throughout the echelons and ~~on~~ for programming the logically motivated sequential ~~sequence issuing~~ presentation of ~~warning~~ the caution, self-checking, intrusion vindication ~~vindicating and alarm-activating~~ signals, and final signals of alarm and ~~activating~~ starting the passive and active measures of protection and defense. The ~~issuing~~ presentation of final signals of alarm and starting the said security measures is the goal function of the new method of ultrasound intrusion detection. ~~[Thus, the said generalized graphic-analytical model represents the mathematical basis for plotting the cause-effect Event-Tree of an intrusion occurrence and for sequent setting the matrix equations that are being solved for Goal Function of intrusion protection that provides for making the logically true decision on~~

~~issuing the signals of intrusion detection, justification and prevention.]~~ ~~The table of **FIG.2** shows also the versions of self-checking in logical signal processing.~~ ~~In another words~~ ~~results in each echelon.~~ ~~This functional feature of signal processing is being foreseen for enhancing the reliability of signal processing procedure itself~~

The inter-echelon informational and processing logical relation is being treated and handled by the logical decision matrix, which is the constituent of the control software algorithm. The said logical decision matrix is being designed by placing top-down into the main column all the sublevels of the echelons and entire echelons in the order of defense-in-depth structure, beginning from echelon **L**, and further by arranging all factors of menaces, drawn from the said echelons' logical equations, in the rows against the respective echelons' sublevels and entire echelons in the order of the diminishing rate of said factors of menaces.

The generalized resolving logical equation is being set up in the result of the analysis of logical decision matrix and generalized graphic-analytical model of the intrusion vulnerability with regard to an intrusion cause-effect cross-linkages among sublevels inside echelons, and among juxtaposed and non-adjacent echelons **C**, **S** and **L**.

The goal function of ultrasound intrusion detection is being resolved during continuous status scan and data acquisition in the steps of:

- solving the echelons' logical equations for justification the fact of intrusion menace; and
- carrying out running analysis of acquired facts of intrusion menaces by logical decision matrix, and
- processing the generalized resolving logical equation by the said control software algorithm with respect to the said verifying logical matrix.

According to the present invention the ~~signal~~ informational and processing logical interrelation ~~in echelon~~ among either juxtaposed or non-adjacent echelons **L**, **S** and **C** [[,]] ~~[i.e. the analysis and justification of said signals]~~ is being ~~carried out~~ treated and handled by the logical decision matrix of the said control software algorithm, which algorithm operates the continuous status scan of all the ultrasonic transceivers and oppositely aligned pairs of transmitters and receivers in every echelon simultaneously, and which algorithm provides for:

- transferring the acquired data of continuous status scan to the said system of echelons' logical equations, verifying logical matrix, and logical decision matrix;

- ability of the resolver, governed by the said software algorithm, to process the acquired data by the said echelons' logical equations, verifying logical matrix, logical decision matrix and generalized resolving logical equation up
  to the logically correct decision of the goal function of the intrusion detection and protection method;
- creation and presentation of logically true sequence of the caution and self-checking signals for every intrusion-suspected echelon, see **FIG.2**, signal of intrusion vindication for the really affected echelon, and final signals of alarm and actuation of security measures where the creation and presentation of the said final signals is the goal function of the new method of ultrasound intrusion detection;
- generation of signals of starting said security measures of active and passive protection and defense which measures include at least: activation of the alarm system, enclosing the physical barriers around the protected works and installations, hence entrapping a trespasser on its actual routing preferably inside echelon **C**, application of disabling tear gas, involving the guard troops, deploying inflatable air obstacles in echelons **S** and **L** or opening the defensive fire therein.

~~on the basis of logically exhaustive signal procedure [applied to the signals, which have been being acquired by continuous status scan of the ultrasonic receivers of all the echelons **C, S and L**]. The logic matrix for analysis of sequence and combination and sequence of [said registered] retrieved signals[~~ [[,]] ~~including the versions of self-checking results in each echelon,] is shown at **FIG.2**. [All the ultrasound responding signals are being registered in real time domain regardless the chosen mode of the said ultrasound signals' response. The said logic signals, see **FIG.2**, is the initial matrix for working out the software algorithm that should be compiled in the form of programmable logic for solving the matrix equations for the Goal Function with use of conditional logic proposition "If ..., then ..." i.e. by applying the logical implication regarding the sequence of the events retrieved from the Event Tree. The said software algorithm provides for:~~

~~– the uninterrupted status scan of the ultrasonic receivers of all the echelons simultaneously that enables to detect the intrusion occurrence either in only one echelon, or in several juxtaposed or non-adjacent echelons at the same time where the self-checking signal are being acquired regularly from every echelon and iteratively from the intrusion-suspected echelons;~~

~~– the continuous comparison of the running status of each echelon and their ensemble with the data from plotted a priory the Event Tree where this Event Tree is being plotted as the representation, in graphic or table matrices, of the interrelation amongst juxtaposed or non-adjacent echelons that is~~

~~based on the sequence of the cause-effect events of: registration of an intrusion occurrence, then defining the vulnerability due to the presence and motion of an intruded subject or trespasser, then undertaking the prior scheduled measures of active and passive protection and defense;~~

~~the designation for each of the echelons the said scheduled measures of active and passive protection and defense that include respectively at least: activating an alarm system, enclosing the physical barriers around the protected works and installations, entrapping a trespasser on its actual routing preferably inside echelon **C**, applying disabling tear gas, involving the guard troops, deploying inflatable airborne obstacles in echelons **S** and **L** or opening the defensive fire therein.]~~

The instrumentation of ultrasound intrusion detection and protection system should consist of at least:

- the resolver, which handles the system of said echelons' logical equations, verifying logical matrix, logical decision matrix of inter-echelon factors of menaces, and generalized resolving logical equation;
- data control block that operates the ultrasound location modes and data acquisition procedure; and
- system control block that forms and presents the signals of intrusion detection, justification and prevention.

~~The suggested by the present invention the novel method of defense-in-depth ultrasound intrusion detection enables to minimize the hardware instrumentation and to simplify the processing software, since it utilizes though different but the only~~

The architectural design of ultrasound processing hardware is being determined basically by use of different ultrasound intrusion detection techniques in each echelon. [[,]]~~which~~ These techniques are based on the different modes of ultrasound signals' responses (i.e. reflection, refraction by edge diffraction and interference[[, e.g.]] by shadowing). The said architectural ~~minimization~~ design ~~of ultrasound processing hardware~~ is being additionally defined by the chosen modes of intrusion monitoring inside every echelon with stationary vectoring or continuous scanning of all the ultrasonic receivers, by optional utilization of Doppler detection technique, and by customized use of the automatic adjustment of emitting-receiving frequency regarding ~~sudden~~ running changes in the ambient air conditions. Thus, there is the evident necessity to minimize the diversity of all hardware and software being utilized in echelons **C**, **S** and **L** in assortment and power consumption.

The said minimization is suggested ~~to be~~ done in the steps of:

- graphical matching of frontiers of juxtaposed echelons for elimination of dead spots of ultrasound

detection, and graphical prototyping of overlapping the protected areas of echelons **C**, **S** and **L** completely with beam patterns of chosen transceivers, transducers and receivers ; and

- conjugation of specification figures of various ultrasound instruments involved, at least such as operating frequency and bandwidth of ultrasound emission, S/N ratio, and type of signal processing domain, which specification figures are destined for practicing different modes of response of ultrasound beam patterns, including reflection, refraction by edge diffraction, and interference with shadowing the emitted beam pattern by a target; and
- unification of instrumentation for different modes of intrusion monitoring inside every echelon with stationary vectoring or continuous scanning of all the ultrasonic receivers, for the optional utilization of Doppler detection technique, and for technique of the automatic emitting-receiving frequency adjustment under running changes in the ambient air conditions.

The aim of the innovative approach of the present invention is to enhance the remotability of ultrasound intrusion monitoring due to the multi-level arrangement of ultrasound surveying network of ~~transducers-receivers~~ transducers and receivers that enables long-range ultrasound location in spite of its intensive attenuation in the ambient air. It permits to meet the requirements of functional diversity and ~~simultaneous~~ operational reliability in various redundant trains of reliable defense-in-depth safety systems. [[, e.g.]]

Therefore, the method and arrangement of effective and stealthy ultrasound intrusion detection according to the present invention are of the evident necessity for protection of Nuclear Power Plants, refineries, offshore rigs, flowing plants of gas-main pipeline, and other civilian and military objects that feature complex spatial component layout. ~~Therefore this method shall be useful and beneficial for critical intrusion protection systems.~~

The present invention is not to be confined to the precise details herein shown and described, nevertheless changes and modifications may be made so far as such changes and modifications indicate no significant deviation from the sense and art of the claims attached hereto.

CLAIMS

What is claimed ~~as new and desired being secured by Letter Patent of the United States~~ is:

Claim 1. (Currently amended) Method of defense-in-depth ultrasound intrusion detection that ~~establishes the purposeful interrelation of various techniques of ultrasound intrusion detection with the aim to ensure an early and anticipatory defense-in-depth intrusion protection throughout a multi-echelon and dome-shaped volumetric space around a surveyed critical installation~~ [[.]] provides for sufficient enhancement of the remote ability of airborne ultrasound location of an intruder throughout ~~a~~ near field ~~dome-type volumetric~~ zone and circumjacent ~~dome-type~~ air vicinity of the ~~layout area that both constitute the entire~~ dome-type volumetric room that surrounds a protected object, including the steps of:

~~arranging~~ arrangement of the said entire volumetric room into the physical, tightly ~~adjacent~~ juxtaposed and preferably geometrically closed areas that constitute the spatial multi-echelon openwork structure of the defense-in-depth automatic intrusion protection system; and

commissioning each of said echelons with the particular task of intrusion detection wherein: the central echelon (**C**) containing the enclosed premises of a protected object is being commissioned to detect the intruder's presence and direction of ingress or egress motion; the short-range single-level or multi-sublevel echelon (**S**) of the near field zone adjoining the buildings, works and installations of a protected object is being assigned to detect the presence and locality of an intruder as far as the direction of its motion; the long-range echelon (**L**) of the circumjacent air vicinity of the layout area of a protected object is being charged with detection of the intruder's presence, and speed and direction of its motion; and

rating the size of each particular echelon in the designed prevailing direction of intrusion location to the dimension that should not exceed the distance at which the airborne ultrasound wave attenuates along its incidence and reflection trip to the value less than the dead band of the ultrasonic transceivers where said transceivers are being chosen regarding their operating frequency and prognosticated conditions of the ambient air around a protected object; and

~~applying~~ application of different modes of response of the emitted ultrasound signal, at least the reflection, refraction by edge diffraction and interference with shadowing by an intruded target, in accordance with the task of intrusion detection and presumptive spatio-temporal conditions of intrusion location in every echelon in particular; and ~~further~~

designing predictive models of intrusion vulnerability of each echelon and the entire area of protected

object regarding previously simulated model of presumptive spatio-temporal behavior of an intruding subject or a trespasser along their possible routings; and

plotting the intrusion event tree that reveals cause-effect relations between an intrusion occurrence and subsequent menaces to echelons and their sublevels therein, and to a protected object integrally; and

derivation of mathematical expressions for the system of logical equations of said cause-effect events for every echelon and its sublevels therein, the verifying logical matrix of intrusion justification, the logical decision matrix of inter-echelon cause-effect relations and factors of menaces, the generalized resolving logical equation; and

drawing up the control software algorithm for governing at least: the resolver, based on the system of said echelons' logical equations, verifying logical matrix, logical decision matrix and generalized resolving logical equation; data control block that operates the ultrasound location modes and data acquisition procedure; and system control block that forms and presents the signals of intrusion detection, justification and prevention; and

establishing the software-programmable inter-echelon informational and processing ~~logic~~ logical interrelation among all the juxtaposed and non-adjacent echelons wherein said interrelation is being ~~performed~~ treated and handled by control software algorithm, which ~~realizes~~[[:]] operates the continuous status scan of all the ultrasonic transceivers and oppositely aligned pairs of ~~transmitters-receivers~~ transmitters and receivers in every echelon simultaneously; and which algorithm provides for:

~~the~~ transferring ~~of~~ the acquired data of continuous status scan to the said system of echelons' logical equations, ~~logic~~ verifying logical matrix, and logical decision matrix ~~control software~~;

~~the processing of~~ ability of the said resolver to process the acquired data by the said echelons' logical equations, verifying logical matrix, logical decision matrix and generalized resolving logical equation up to the logically correct decision of the goal function ~~on the basis of the prior model of intrusion vulnerability of each echelon and the entire area of a protected object, and on the basis of simulated a priori the model of the presumptive spatio-temporal behavior of an intruding subject or a trespasser where the said models serve for preliminary plotting the Event Tree~~ of the intrusion detection and protection method; and

~~the~~ creation and ~~issuing the~~ presentation of logically true sequence of the caution and self-checking signals for every intrusion-suspected echelon, signal of intrusion vindication for the really affected echelon, and final signals of alarm and activation of security measures where the ~~issuing~~ creation and presentation of the said final signals is the goal function ~~being~~

~~fulfilled as a result of solving the matrix equations that reveal the Goal Function~~ of the new method of ultrasound intrusion detection and protection [[.]]; and

generation of signals of starting said security measures of active and passive protection and defense, which measures include at least: activation of the alarm system, enclosing the physical barriers around the protected works and installations, hence entrapping a trespasser on its actual routing preferably inside echelon **C**, application of disabling tear gas, involving the guard troops, deploying inflatable air obstacles in echelons **S** and **L** or opening the defensive fire therein.

Claim 2. (Currently amended) Method as defined in Claim 1 wherein all the ~~whole of~~ protected dome-type volumetric room around a critical ~~installation~~ object is being arranged in several juxtaposed ~~areas, which areas are being defined as interrelated~~ ~~single-level or multi-sublevel~~ echelons ~~of an entire defense-in-depth intrusion detection space~~ [[.]]; where

~~where~~ the indoor single-level or multi-sublevel echelon **C** is being arranged inside the enclosed premises of a protected object, in each of which at least one couple of ~~transmitter-receiver~~ transmitter and receiver is being mounted for inward location of an intruder by ultrasound beam responding in reflection or refraction by diffraction modes; and where

~~where~~ the outdoor single-level or multi-sublevel echelon **S** of the near field zone adjoining the buildings and installations of a protected object is being shaped to consist of 2-D polygonal or curvilinear plane contours, and/or 3-D curved surface areas that are connected into the spatial solid openwork frame, ~~that is being~~ equipped with the pairs of oppositely directed transmitters and receivers, so that all this near field zone has been covered by closely adjacent or even overlapped ultrasound beam patterns, which are being designated to respond either in the refraction mode characterized with diffraction of receiver's beam pattern by intruder's edge, or in the mode of interference featured shadowing a receiver's beam pattern by an intruding subject or trespasser; and further where

~~where~~ the echelon **L** of circumjacent ~~dome-type~~ air vicinity of the layout area of a protected object is being shaped into 3-D curved surface in the form of substantial spatial lattice equipped with outwardly directed transceivers that function by the techniques of ~~preferably~~ constant vectoring or scanning the solid angles that overlap each other, and operate in the mode of continuous emission of ultrasound beams and occasional reception of said beams ~~once having been~~ reflected ~~by~~ from a target.

Claim 3. (Currently amended) Method as defined in Claim 2, including the steps of: ~~wherein~~

shaping the inner boundaries of outdoor single-level or multi-sublevel echelon **S** of the near field zone in compliance with layout and overground contours of installations and works of a protected object, while shaping the outer frontiers of the said echelon in compliance with layout and outside contours of a headwork and buildings of a protected object; and

~~dividing~~ division of the outdoor echelon **S** of the near field zone into a few sublevels and designing the geometrical shapes and dimensions of said 2-D polygonal or curvilinear contours, or 3-D curved surface areas ~~are being~~ put in ~~correspondence to~~ accordance with:

the spatio-temporal parameters of air-borne ultrasound propagation towards prevailing directions of ultrasonic location in forecasted conditions of the air ambient, while admitting the airborne ultrasound wave attenuation along its one-way emission trip from a transmitter to the opposite receiver to have occurred to the value not less than the dead band of the ultrasonic transceivers [[,]];

the presumptive spatio-temporal behavior of an intruder or trespasser over the terrain of the said echelon of a protected object regarding their possible routings [[,]];~~as far as to~~

the available capabilities ~~of covering~~ to cover all the said surfaces with the ~~appropriate~~ ~~stationary or scanning~~ ultrasound beam patterns ~~during surveillance~~ chosen regarding the said conditions of ultrasound propagation and applied either in stationary or scanning modes of surveillance [[.]]; and

shaping the echelon **L** of circumjacent ~~dome-type~~ air vicinity of the layout area of a protected object so that it is being done open outwardly to the dome-type surveyed room ~~but its~~ whereas the inside geometrically closed frontier of echelon **L** is being configured as the openwork spatial lattice, enveloping the external frontier of the outdoor echelon **S** of the near field zone, otherwise the said both frontiers are being constructed to coincide in part or in full.

Claim 4. (Currently amended) Method as defined in Claims1, 2 and 3 ~~wherein a proper~~, including the steps of:

working out the graphic-analytical model of intrusion vulnerability for each echelon ~~is being composed~~ with regard to the supposed options of ~~supposed~~ spatio-temporal purposeful behavior of intruder or trespasser [[,]] along their possible routings inside premises of the central echelon **C**, around buildings and works of short-range echelon **S**, ~~in the~~ within reach of ultrasound location inside the space of the long-range echelon **L**, where the said options of their ingress or egress routings thru every echelon are being ~~elaborated~~ searched with taking to account the layout and architectural

features of the available protective barriers against an intrusion, and various assumed ways of the trespassers' accessibility to the critical works and installations therein; and

~~verifying~~ verification of ~~which graphic-analytical model is being used for verifying~~ geometrical shape and dimensions of every echelon ~~of the said entire defense-in-depth intrusion detection space~~[[.]] with respect to its ~~pertained~~ predictive graphic-analytical model of intrusion vulnerability where the said verification is being accomplished by comparison of spatio-temporal parameters of intruder's or trespasser's purposeful behavior with spatio-temporal parameters of ultrasound beams' propagation and signaling response in prevailing directions of location.

Claim 5. (Currently amended) Method as defined in Claims 1, 2 and 3 wherein the ~~appropriate~~ technique of ultrasound intrusion detection for each of said echelons ~~that features the distinctive mode of emitting ultrasound signal and registration of its disturbances~~ is being chosen ~~and assigned regarding the type of ultrasonic beam responding, i.e. reflection, refraction by diffraction and interference, which types of ultrasonic beam responding are being respectively selected in compliance with previously composed worked out~~ ~~following~~ in the steps of:

selection of modes of ultrasonic beam ~~responding~~ response regarding the task which particular echelon has been commissioned with and in compliance with previously worked out the predictive graphic-analytical models of intrusion vulnerability for each surveyed echelon[[.]]; and

~~defining~~ definition of the layout chart for ~~disposing~~ disposition of ultrasound transceivers ~~having been~~ distributed inside premises of the echelon **C** and mounted along the circumference of the echelon **L**, and for ~~arranging~~ arrangement of the oppositely aligned pairs of transmitters and receivers along either adverse sides of the integral contour of single-level echelon **S** or adverse sides of the joining contours of juxtaposed portions of ~~multi-level~~ multi-sublevel echelon **S** where the said ~~disposing~~ disposition and ~~arranging~~ arrangement are being schematized in the form of the straight-line or elbow-type rows, planar array or in the spatial lattice for each of the said echelons with respect to the said predictive echelons' graphic-analytical models of intrusion vulnerability and with obeying the requirements to tightly covering at least possible routings of intruders or trespassers with ultrasound beam patterns operating in stationary or in scanning mode of location.

Claim 6. (Currently amended) Method as defined in Claims 1 and 4 wherein the generalized graphic-analytical model of intrusion vulnerability for the entire protected dome-type volumetric room around a critical ~~installation~~ object is being composed, ~~which model is being created with the aim to establish an operatively reliable and functionally correct signal-processing interrelation amongst different~~

~~adjacent echelons based on the principle of early and anticipatory ultrasound detection of ingress or aggress intrusion thereinto~~ [[.]] including the steps of:

~~graphical matching of frontiers of juxtaposed echelons for elimination of dead spots of ultrasound detection and for minimizing the number of transceivers, transmitters and receivers to be used; and~~

~~graphic-analytical estimation of inter-echelon dependable vulnerability at occurrence of one or a few intrusions in one of the echelons, or in some of them simultaneously; and~~

designation of available physical barriers for having used them as hindrances ~~of reaching~~ to access the critical installations and as entrapments along the presumed routings of an intruding subject or a trespasser where this designation is being fulfilled regarding the previously simulated ~~a priori the~~ model of the presumptive spatio-temporal behavior of an intruding subject or a trespasser; and

definition of the territorial contours and limits of ~~operation~~ operating time, ~~violating~~ violation of which with the non-authorized presence or movement of an intruded subject or a trespasser should be considered ~~to be~~ as the actual hazardous intrusion; and

~~assigning the Goal Function~~ of intrusion ~~protection of a critical object as the issuing the signals of intrusion detection, justification and prevention with finalized issuing the signals of alarm and activating of passive and active security measures where issuing the said signals is being accomplished as a result of solving the matrix equations as the logically true decision of the software algorithm.~~

plotting the intrusion event tree in the form of graphic representation or table matrices which identify the interrelations of sublevels inside any echelon, and among juxtaposed or non-adjacent echelons that are based on the sequence of the cause-effect events of registration of an intrusion occurrence and definition of the vulnerability and menaces due to the presence and motion of an intruded subject or trespasser, where

the graphic presentation of intrusion event tree is being fulfilled on the floor plans of enclosed premises of echelon **C** and on the lay-out of the near field zone of echelon **S** for detection of intrusion cause-effect cross-linkages and respective facts of intrusion menaces among sublevels inside echelons, and among juxtaposed and non-adjacent echelons **C**, **S** and **L**; and where

the revealed data of said cross-linkages and facts of intrusion menaces are being used for setting up and analysis of said logical decision matrix, and for setting up said generalized resolving logical equation; and further

setting up the generalized graphic-analytical model itself in the form of graphic-analytical

representation of inter-echelon dependable vulnerability at occurrence of one or a few intrusions in one of the echelons, or in some of them simultaneously.

Claim 7. (Currently amended). Method as defined in Claims 1 and ~~6~~ 5 wherein the diversity of hardware and software of all the techniques of ultrasound intrusion detection ~~involved~~ used in ~~juxtaposed and non-adjacent~~ echelons **C, S** and **L** is being ~~chosen in accordance with said different modes of response of ultrasound signals utilized~~[[;]] ~~and~~

~~where the said hardware and software is being~~ minimized in assortment and power consumption ~~with the aim of consequent assembling the mutual set of instruments and prepare the appropriate software for logically exhaustive the defense-in-depth intrusion detection signal processing.~~ ~~on~~ in the steps of:

graphical matching of frontiers of juxtaposed echelons for elimination of dead spots of ultrasound detection and graphical prototyping of overlapping the protected areas of echelons **C, S** and **L** completely with beam patterns of chosen transceivers, transducers and receivers ; and

~~bases of the~~ conjugation of specification figures of various ultrasound instruments involved, at least ~~like~~ such as operating frequency and bandwidth of ultrasound emission, S/N ratio, and type of signal processing domain, which specification figures are destined for practicing different modes of response of ultrasound beam patterns, including reflection, refraction by edge diffraction, and interference with shadowing the emitted beam pattern by a target[[,]] ~~which modes should be used in juxtaposed and non-adjacent echelons of intrusion protection room around a critical object~~; and

~~where the architectural minimization of ultrasound processing hardware is being additionally defined by the chosen~~ unification of instrumentation for different modes of intrusion monitoring inside every echelon with stationary vectoring or continuous scanning of all the ultrasonic receivers, for the optional utilization of Doppler detection technique, and ~~by customized~~ for technique ~~application~~ of the automatic emitting-receiving frequency adjustment ~~in the event of sudden~~ under running changes in the ambient air conditions[[;]] ~~and further~~ .

~~where the processing software is being worked out in the form of software algorithm on the basis of information and processing logic matrix, which interprets mathematically the Goal Function of issuing the signals of intrusion detection, justification and prevention in the result of logical processing of caution and self-checking signals, acquired during continuous status scan of ultrasound detectors in all the echelons of the intrusion protection system~~[[.]]

Claim 8. (Cancelled).

Claim 9. (**New**) Method as defined in Claims 1, 4 and 6 wherein

the echelons' logical equations are being set up in advance to reveal the factors of menaces inside the echelons and sublevels therein based on the said graphic-analytical models of intrusion vulnerability that is being estimated by the failure probability of protected facilities, especially of the facilities, belonging to some sublevels in one echelon or to different echelons concurrently; where

the logical decision matrix of the control software algorithm is being designed by placing top-down into the main column all the sublevels of the echelons and entire echelons in the order of defense-in-depth structure, beginning from echelon **L**, and further by arranging all factors of menaces, drawn from the said echelons' logical equations, in the rows against the respective echelons' sublevels and entire echelons in the order of the diminishing rate of said factors of menaces; where

the verifying logical matrix is being designed for carrying out logic analysis for trustworthiness of inter-echelon caution and self-checking signals to avoid untruth propositions during resolution of the goal function by the generalized resolving logical equation of the control software algorithm; and where

the said generalized resolving logical equation is being set up in the result of the analysis of logical decision matrix and generalized graphic-analytical model of intrusion vulnerability with regard to the intrusion cause-effect cross-linkages among sublevels inside echelons, and among juxtaposed and non-adjacent echelons **C**, **S** and **L**.

Claim 10. (**New**) Method as defined in Claims 1 and 9 wherein the goal function of ultrasound intrusion detection is being iteratively resolved during continuous status scan and data acquisition in the steps of:

solution of the echelons' logical equations for justification the fact of intrusion menace; and

carrying-out running analysis of acquired facts of intrusion menaces by logical decision matrix, and

processing the generalized resolving logical equation by the said control software algorithm with respect to the said verifying logical matrix.

~~ABSTRACT~~ ABSTRACT OF THE DISCLOSURE

Method of ultrasound intrusion detection is disclosed wherein the ultrasound surveillance in volumetric multi-area room ~~volumetric~~ ~~surveillance~~ is being organized to meet ~~properly~~ the~~-correspondent~~ requirements to faultlessness in providing for the preventive defense-in-depth intrusion protection of critical objects. All the room around a protected object is being purposely arranged in juxtaposed volumetric substantial areas, which areas are closed or open and do represent respectively the central, short-range and long-range echelons of an entire defense-in-depth protection ~~space~~ structure. The pertain method of ultrasound detection of either ingress or ~~aggress~~ egress hazardous intrusion is being realized in each ~~adjacent~~ echelon regarding the specific task, which this very echelon has been commissioned with. These methods are being based ~~preferably~~ upon the phenomena of reflection, refraction by edge diffraction and interference by shadowing of narrowly directed ultrasound beams [[,]] ~~which~~ . The said beams are being closely disposed in 2-D curvilinear or polygonal array, or in 3-D curved surface lattice ~~arrangement of~~ onto multi-level solid openwork frames arranged in different echelons of a protected object. ~~and~~ These ultrasound beams are being activated for target detection with use of ~~either~~ unit stationary vector directing , stationary vector lattice arranging or unit/group vector scanning ~~scan~~ ~~conversion~~ techniques. Processing ~~and displaying~~ of ~~self-checking~~ [[,]] caution, self-checking, intrusion vindication, and alarm signals is being accomplished on the basis of logical programming ~~of the Goal Function~~ of control software algorithm for ~~issuing~~ presentation of alarm and security activating signals, and with the same kind of hardware and software for each ~~method~~ of the said ultrasound ~~detection~~ beams' response phenomena involved ~~that~~. Having been put in practice the present invention shall enhance the ~~reliability~~ remote ability, trustworthiness and cost-effectiveness of the ultrasound detection of ingress or ~~aggress~~ egress intrusion throughout the ~~adjacent volumetric~~ ~~substantial~~ ~~protection~~ areas of protected critical objects.

[[7]] [[8]] 9 Claims, 2 Drawing Sheets